1up

NASA TECHNICAL TRANSLATION NASA TT F-15,550

METHODS OF FILTERING PHOTOGRAPHIC IMAGES AND THE POSSIBILITY OF THEIR USE IN GEOLOGY

V. B. Komarov, V. F. Nomokonova
and Yu. V. Uglev

Translation of "Metody Fil'tratsii Fotoizobrazheniy i Vozmozhnosti ikh Primeneniya v Geologii," Academy of Sciences USSR, Moscow, April 1974, 9 pp.

(NASA-TT-F-15550) METHODS OF FILTERING PHOTOGRAPHIC IMAGES AND THE POSSIBILITY OF THEIR USE IN GEOLOGY (Kanner (Leo) Associates) 10 p 4.00 CSCL 14E
N74-22100
Unclas
G3/14 36848

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D. C. 20546 APRIL 1974

STANDARD TITLE PAGE

1. Report No. NASA TT F-15,550	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle METHODS OF FILTERING PHOTOGRAPHIC IMAGES AND THE POSSIBILITY OF THEIR USE IN GEOLOGY		5. Report Date April 1974
		6. Performing Organization Code
7. Author(s) Komarov, V. B., Nomokonova, V. F. and Uglov, Yu. V.		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates Annapolis, Maryland		11. Contract or Grant No. NASw-2481
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address NASA, Code KSS-1 Washington, D. C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes Translation of "Metody Fil'tratsii Fotoizobrazheniy i Vozmozhnosti ikh Primeneniya v Geologii," Academy of Sciences USSR, Moscow, April 1974, 9 pp.

16. Abstract

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified. Unlimited.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	10	4.00

NASA-HQ

METHODS OF FILTERING PHOTOGRAPHIC IMAGES AND THE POSSIBILITY OF THEIR USE IN GEOLOGY

V. B. Komarov, V. F. Nomokonova
and Yu. V. Uglev

Photographic surveying, producing images of the Earth's surface, is at present one of the leading methods as to volume of information produced and breadth of its application in geological-geographic studies and in the economy. The photographic image, as a source of information, transmits individual features of natural objects in the visible area of the spectrum in model form, allowing them to be studied under office conditions. This representation of information defines the general principle of formal analysis of objects of investigation by the use of the quantitative characteristics of the photographic image (intervals of optimal density, spatial frequencies or linear and angular dimensions of elements, as well as the characteristics of their distribution in space). /1*

During the preliminary stage of analysis of objects being studied on photographs, the problem consists in determination of the informative elements of their image, i.e., those elements which have a characteristic photographic representation. However, it is difficult to find and object for which all properties defining its condition at the moment of photography are typical. Therefore, separation of the informative elements of an image must be performed differently, depending on the significance and degree of manifestation of individual properties or groups of properties on the photograph. If these properties of the object are clearly and unambiguously expressed in some feature of the photograph, then this feature is called characteristic. In this case, the portion of the image selected,

*Numbers in the margin indicate pagination in the foreign text.

on which the feature is represented, corresponds to an informative element.

The ambiguity of separation of informative elements of an image arises when there is uncertainty in the expression of the properties of the object. Features of the photograph in this case take on their values in partially or fully overlapping intervals. In this case in practice only a fraction of the informative elements can be distinguished, and the others are lost. /2

It is natural to assume that if the interpreter encounters difficulties in evaluating the overlapping features of a photograph, it might be more effective to use technical means for processing of images. These means include various methods of filtration, requiring special transformation of the photographic images, in order to select informative elements.

Recently, two groups of methods of image filtration have been intensively developed: electronic and optical. However, they have not yet gone beyond the stage of experimental testing. Due to the high cost of computers and the complexity of information input-output devices, we can consider these means effective only when the required programs have been written and a combined image processing system produced.

Therefore, in addition to these promising trends, one quite pressing task for today is the development of simple filtration methods and equipment. These include methods of "photographic filtration" of images which are equivalent to those just mentioned in a number of characteristics for many practical applications. These characteristics include: possibility of parallel (without scanning) processing of photographic information; possibility of reproduction of the basic sequence of linear mathematical operations performed on an image; possibility of construction of typical operators and algorithms for filtration. The relative simplicity of the technology of transformation of an image provides the required conditions for broad utilization of these images in the practice of geological interpretation. The slight cumbersomeness of the process of filtration, requiring multistage conversion of the initial image, is compensated by the quality of the result produced. The direct participation of the interpreter himself in the processing of the materials is quite important, since the interpreter may have to check and alter the process at any stage. /3

The various methods of photographic filtration are based on various principles. For example, in some methods it is characteristic that special approaches are used to control the photographic process by changing the photochemical processing of the materials.

Another approach which has been studied in the Laboratory of Aerial Methods is based on the application of various filters in the process of photographic transformation. These filters are classified according to their physical principle into two main types:

-- filters with selective transmission: sharp and unsharp copies of the initial image (negatives or positives); copies with variation in the gradiation characteristics; images produced in narrow spectral ranges ("zone filters"); images differing in exposure time from the initial image; rasters of various structure, etc.;

-- filters with selective scattering of the light flux. These include ground glass, plain-parallel glass plates of various thicknesses and certain organic materials.

The use of these filters in a system consisting of "initial image -- filter -- converted image" allows the required transformations to be made, involving separation (selection) of elements of the initial image on the basis of the photographic features mentioned above. Analysis of such a system from the standpoint of the theory of modulation transmission allows us to /4 construct the corresponding standard conversion operators which, in turn, can be used to construct standard algorithms for image filtration in the form of specific structural flow charts.

This approach to the realization of the filtration process using photographic equipment involves the creation of a decision element (by analogy with mechanical, electromechanical, electronic and other decision elements), which can be arbitrarily defined as a "photographic" decision element. The use of a photographic decision element will be fruitful in the respect that it allows structural methods to be used in the framework of the theory of control systems for the performance of functional transformation of images, including successive transformations, parallel and series-parallel transformations. All of this allows us to control the processing of the materials.

Photographic filtration algorithms involve the construction of a multistage image processing system. At the present time, the following algorithms for separation of initial image elements have been created and experimentally tested: by level or interval of optical density; space-frequency division; division on the basis of dimensions of element form and their spatial position. In practice, these algorithms are realized by the application of the following group of methods in various combinations: equidensity, defocussing and unsharp masking, raster, mismatch and certain special methods of additional transformation (amplification, discretization, etc.).

Using standard algorithms for photographic filtration, we can produce new (transformed) images, transmitting the informative elements of the initial image, which are difficult to establish, or sometimes simply impossible to determine, by /5
simple visual analysis. These elements include: sectors of the initial image characterizing identical intervals of optical density; contours of the images; sectors with identical linear and angular dimensions of elements; sectors with elements of

a common thickness (density) of distribution per unit area of the photograph; local elements -- breaks in contours (corner points) or, in one particular case, intersections and branchings (junction points); points of symmetry; axes of geometric configurations, etc.

We should indicate the possibility of filtration of "zone" images, produced in various spectral intervals, as well as "sequential" images of an object, photographed at different times. The corresponding processing allows informative elements which differ only in certain spectral intervals, as well as "static" and "dynamic" elements, belonging to objects with physical properties which vary with time, to be reproduced in the converted images.

Methods of photographic filtration can also be used for such important operations as "generalization" of informative elements and their schematic representation in the form of arbitrary graphic models, similar in form and content to primary map plans ("pre-maps") made up by interpreters.

This is a far from complete list of the possible conversions of photographic images performed by photographic methods, designed to separate informative elements. Considering the broad range of problems related to the analysis of the theoretical and practical foundations of this problem, let us discuss in more detail the analysis of but a single version, namely the problem of separation of informative elements related to the detemination of the structural properties of geolotical /6
objects.

As we know, the nature of tectonic structures may be manifested in theorientation of their elements (cracks, faults, etc.). These elements appear on photographs as line details of various lengths. During the stage of preliminary analysis of the images of sections within which structures may appear, the task at hand consists of determination of zones containing elements with identical orientation. There is also practical interest in any zone with regular orientation of its elements relative to an arbitrary center. These may be elements converging on a certain center at various angles to each other, elements located around circles, etc. Figure 1 shows a number of hypothetical models of such placements of elements.

The objective solution of the problem of separating such elements can be facilitated by the raster method of filtration of images.

The principle of raster filtration of image elements consists in the projection of the initial image (negative), containing a set of extended elements of various directions, along with a linear regular raster. As the raster is rotated relative to the nonmoving initial image, structural transformation of the bundle of rays passing through the image and the raster occurs. As a result of this, differences in the brightness of the light flux appear at the output of the system for differently directed elements of the initial image. This effect can be recorded on light sensitive film in the form of a converted image with the extended elements of the initial image perpendicular to the lines of the raster separated. These elements will appear darker than image elements with other orientations /7
relative to the raster lines.

This can be illustrated by the following example. Figure 2 shows the initial image of a test with extended elements located at various angles to each others. Filtration of this image was used to produce the first, second and third converted images (Figure 2b, c, d). Analysis of this figure makes the effect of qualitative separation of images of elements oriented in directions I-I, II-II and III-III obvious. Analysis of this figure also indicates the genuine possibility of separating extended elements within the limits of a rather narrow angular interval $\Delta\alpha \simeq 2°$ (Figure 2d). The separation of elements of the initial image in directions I-I and II-II is achieved by even rotation of the raster relative to the nonmoving initial image over a sector limited by the interval selected $\Delta\alpha_i$. Recording of the converted light flux on light sensitive material allows a new image to be produced with elements oriented at various angles not going beyond the angle interval selected $\Delta\alpha_i$.

Of the arsenal of technical devices for production of converted images, a special raster optical system -- ROS -- is used. This system, in addition to a regular linear film raster, also includes an optical element (lens); this element and the raster act to receive and transform the light flux passing through the initial image.

The ROS includes (Figure 3): an evenly illuminated screen with a correcting filter mask (equalizing the ilumination of the field), a linear raster, a lens and a cassette carrying the light sensitive film, a screen on which the initial image to be analyzed is placed, through which the light flux is transmitted, /8 while the raster converts the flux from the initial image, transmitting its elongated details perpendicular to the lines of the raster. The lens further directs the light flux to the radiation receiver -- the cassette with its light sensitive film. Rotation of the raster relative to the image being analyzed is performed by a reversing motor, supplied by a stabilized direct current power supply. The required section of rotation of the raster by angle α_i is selected by a special mechanism.

The results produced using the ROS are shown in Figures 4 and 5. These figures show the converted images with elements of one strike, using the contoured (shaded) crack figure and tone image as the initial images.

The use of rasters of other structures (concentric circles, angle sectors, etc.) in this system allows other initial image elements such as circular structures, linear elements converging toward a certain center, etc. to be differentiated.

FIGURE CAPTIONS

/9

Figure 1. A. Schematic representation of certain elementary types of symmetry of elements encountered in actual images.

B. Schematic representation of certain types of rasters (a) and elements separated using these rasters (b).

Figure 2. Conversion of a test image with linear elements at various angles by means of a raster optical system (ROS). A, Initial test image; b, Test image with elements separated within a section with angular interval $\Delta\alpha = 90°$; c, Test image with elements selected within a sector with angular interval $\Delta\alpha = 30°$; d, Test image with individual elements separated.

Figure 3. a, General view of raster optical system (ROS); b, Diagram of ROS. The figure shows:

1. Screen with correcting filter
2. Image analyzed
3. Film line raster in its mount
4. Lens
5. Cassette with light sensitive film
6. Reversing motor which rotates the raster
7. Raster rotation angle setting mechanism
8. Motor power supply

Figure 4. Example of separation of crack elements in two directions "a-a" and "b-b"

Figure 5. Example of separation of linear elements of various orientations from initial half tone image. a, Initial aerial photograph; b, c, Converted images with separation of linear elements from image "a".